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## Analysis of Pollutant Concentrations in Air-condition Room with Different Types of Air Supply

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### Abstract

In order to improve the air quality of the offices with pollutant and reduce the concentrations of it to satisfy the demand of workers for health. This paper simulated three different types of air supply, three different air volume and three different concentrations of pollutant and obtained indoor pollutant concentrations under different ways and different air pollutant emission power. The comparison of results show that the air supply of up-inlet and down-outlet on the same side have a better decontamination effect than other two types of air supplies. Increasing the quantity of fresh air can significantly reduce the concentrations of indoor pollutants, so does reducing pollutant emission power. Results indicate that if we want to control the indoor pollutant concentrations, the methods of up-inlet and down-outlet on the same side should be adopted, which could increase the volume of fresh air and reduce the concentrations of the pollutant.

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**Keywords:** top-inlet and side-outlet; up-inlet and down-outlet on the same side; up-inlet and down-outlet on the opposite side; the concentrations of pollutant

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### 1. Introduction

Recent studies have shown that the effects of indoor air pollution are worse than outdoor air pollution. Effects of air pollution on human health mainly happen in the Interior. For staff members working for a long time in the office, it is prone to throat irritation, cough and other symptoms, and these symptoms is closely related to the pollutant released by office equipment. Guo[1] studied the concentrations levels and composition spectrum of the BTEX

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produced by the printer as a complex source, It was found that the indoor personnel BTEX total carcinogenic estimates reached more than 12 times the human cancer risk value that the EPA designated. Evaluation of pollutant concentration in the air is an important indicator of indoor air quality. Monitoring and research on distribution of indoor pollutant concentrations are important for evaluation of indoor air quality. Liu et al.[2] and others use air supply model, initial conditions and pollution source dispersion model introduced a formula for the distribution of contaminant concentration and validated by experimental data. Feng et al.[3] simulated the motion distribution pattern of aerosol particles released by body continuing to speak under different airflow organized forms, and explored the rational form of air-conditioned room air distribution. Li et al.[2] selected the conference room for the study, then simulated how smoking affect indoor particulate matter concentration in the form of two different ventilation and compared the merits of the two forms of ventilation. On the basis of previous studies, this paper treat printing device for indoor air-conditioned room sources, will numerical simulate and compare the air pollutant dispersion under three different ways to determine the air supply manner in favor of air pollutant dispersion caused by office equipment.

## Nomenclature

$\Phi$	universal variables, which can be a scalar or a vector
$\Gamma_\phi$	generalized diffusion coefficient
$S_\phi$	a general source

## 2. Methods

### 2.1. Physical model

This paper uses Airpak Software model building with the size of 4.8m×4m×3m ( length × width × high ). Office is shown in figure 1. The door is located at the west wall, and windows on the east side of the wall, diffuse source of pollutant on the north side of the printer.

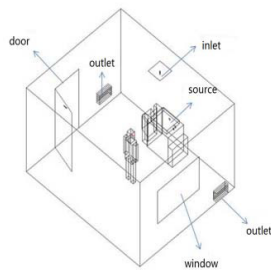


Fig. 1 The model of top-inlet and side-outlet air supply

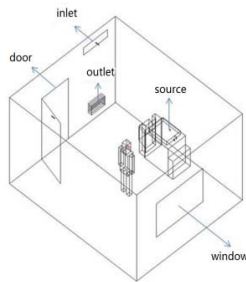


Fig. 2 The model of the same side up-inlet and down-outlet air supply

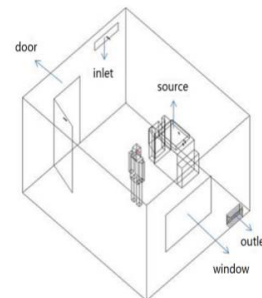


Fig. 3 The model of the opposite up-inlet and down-outlet air supply

Fig. 1. Simplified building model

Study in this paper was carried under three different kind of air distribution model, which namely: 1) top-inlet and side-outlet air supply model, as shown in figure 1; 2) the same side up-inlet and down-outlet air supply model, as shown in figure 2; 3) the opposite up-inlet and down-outlet air supply model as shown in figure 3 below. In addition to the positions and sizes of air inlet and outlet (table 1), All the remaining layout in the simulation room are the

same. Return air inlet dimensions in the model are the 0.5m×0.3m (length × width), from the ground 0.2m.

Table 1 Vent size and location of the three kinds of air supply

Type	Air supply outlet	Air velocity (m/s)	The location of in-let	The location of out-let
up-inlet and side-outlet	louver (500mm×500mm)	2.5	on the north side of the ceiling	down the eastern and western wall
up-inlet and down-outlet on the same side	louver (900mm×250mm)	2.5	up the western wall	down the western wall
up-inlet and down-outlet on the opposite side	louver (900mm×250mm)	2.5	up the western wall	down the eastern wall

## 2.2. Mathematical model

Many experiments have shown that: the most of airflow in air conditioning room are turbulence, according to actual conditions of unsteady turbulence model for numerical simulation of indoor airflow distribution. So we use k-ε two equation model of turbulent convective heat transfer problems, k-ε equation and the conservation of momentum equation, the conservation of energy equation and the equation of continuity form the control of indoor air flow equation, and its generic forms, such as type 1 shown below. Airpak software by means of numerical methods to solve equations, of general equation of dimensionless variables, and control volume method and staggered grid for general equations for discrete and difference scheme using mixed formats, algorithms for SIMPLE.

$$\frac{\partial}{\partial t}(\rho\phi) + \nabla \cdot (\rho V \phi_i) = \nabla \cdot (\Gamma_\phi \nabla \phi) + S_\phi \quad (1)$$

$\phi$  is universal variables, which can be a scalar or a vector;  $\Gamma_\phi$  is the generalized diffusion coefficient;  $S_\phi$  is a general source.

## 2.3. Boundary conditions and initial conditions

Three essential boundary conditions of the model are studied in this paper. 1) The initial air supply air volume is 470m<sup>3</sup>/h and velocity is 2.5m/s; the temperature of supply air is 20°C; 2) The window is under static pressure and temperature is 20°C, temperature is 20°C outside the window; 3) In addition to an indoor pollution source, other objects do not emit heat to the outside.

## 3. Results

### 3.1. Effects of different ventilation on indoor pollutant distribution

This paper simulated and analysed the pollutant concentrations distribution of human activity region and air inlet and outlet areas under different air distribution modes. Figure 4 shows the pollutant concentrations at staff position along the X, Y, Z direction distribution under different air supply modes. And Figure 5 and Figure 6 show the pollutant concentrations distribution near the inlet and outlet under different air supply modes. Then from Figure 7, Figure 8 and Figure 9 we can see the air pollutant diffusion trajectory in different periods under three different air supply modes. At last, Figure 10, Figure 11 and Figure 12 is for the different staff positions under three different concentration contours, in which a is the air supply of top-inlet and side-outlet, b is the air supply of up-inlet and down-outlet on the same side, c is the air supply of up-inlet and down-outlet on the opposite side. V1 represents the top-inlet and side-outlet air pollutant concentration curve, V2 is represented by the up-inlet and down-outlet on the

same side air pollutant concentration curve, V3 is the up-inlet and down-outlet on the opposite side the representative of air pollutant concentration curve.

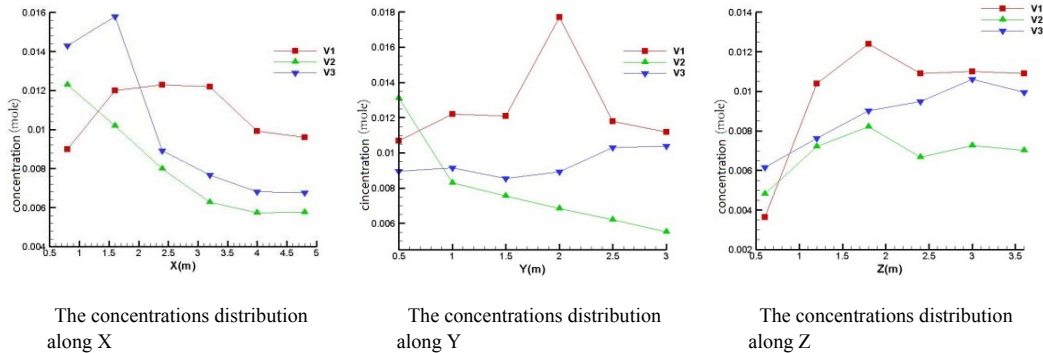


Fig. 4. The distribution of pollutant concentrations in working areas under three different air supply

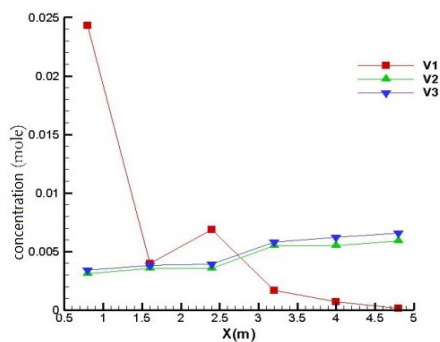


Fig.5 The distribution of pollutant concentrations at the vent of outlet

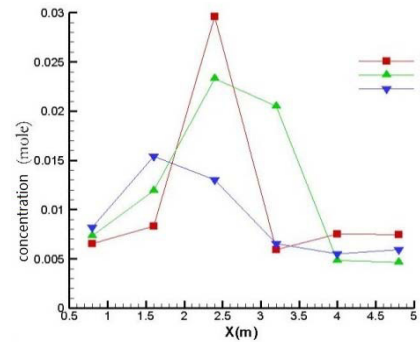
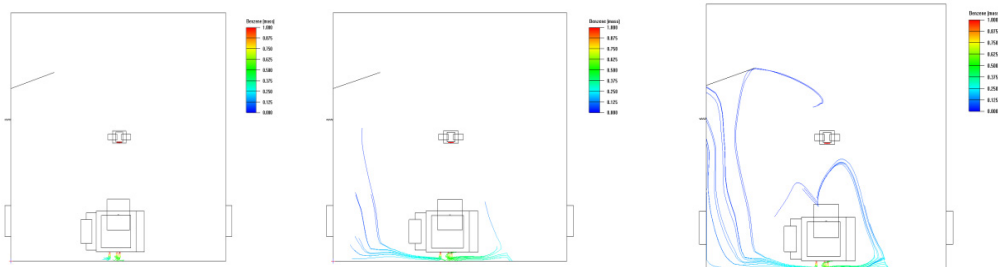


Fig.6 The distribution of pollutant concentrations at the vent of return air

As we can see, the air supply of up-inlet and down-outlet on the same side owns a better decontamination effect than the other two air supply modes, it makes a lower indoor pollutant concentrations when reaching a steady state (Figure 4). Figure 5 and Figure 6 reveals that: 1) with the air supply of up-inlet and down-outlet, the pollutant concentrations near the air outlet is basically same and barely change, while the pollutant concentrations of up-inlet and side-outlet air supply model increased with the distance from the air outlet; 2) all the three kinds of air supply modes have the same trends of concentrations distribution near the outlet, there is a maximum concentrations point. Relatively speaking, the air supply of up-inlet and down-outlet on the opposite side makes lower concentrations near the outlet.





possible as it can under the condition of satisfying the person's comfort to reduce indoor pollutant concentrations.

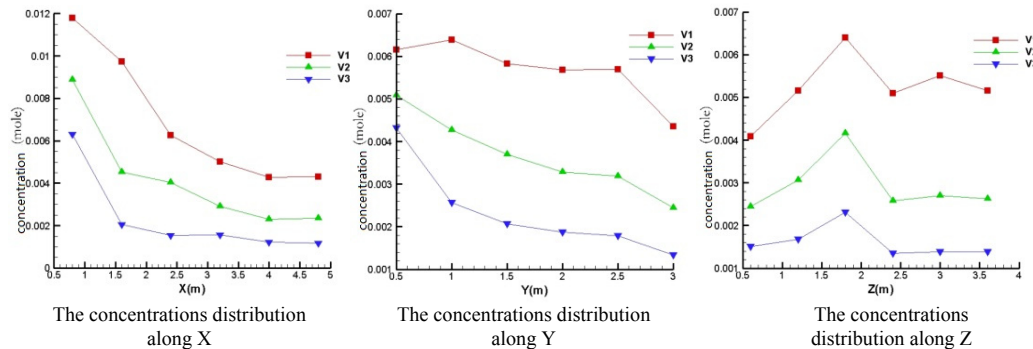


Fig. 11. The distribution of pollutant concentrations in work area under different supply air rates

### 3.3. Effects of pollution source concentrations on the indoor pollutant concentrations distribution

In former simulation, the concentrations of pollutant source was set to 1mole/m<sup>3</sup>. Next, the simulation will analyse the pollution concentrations changes along three directions at the staff position ( $X_0=2.4\text{m}$ ,  $Y_0=2\text{m}$ ,  $Z_0=1.5\text{m}$ ) at three different pollution source concentrations, which are 0.25mole/m<sup>3</sup>, 0.50mole/m<sup>3</sup> and 0.75mole/m<sup>3</sup> respectively. Besides, the air supply mode is up-inlet and down-outlet on the same side. The distribution of pollutant concentrations in staff position under different source concentrations are shown in Figure 12. In the following figures, V1 represents the pollutant concentrations of 0.25mole/m<sup>3</sup>, V2 on behalf of 0.50mole/m<sup>3</sup>, and V3 on behalf of 0.75mole/m<sup>3</sup>.

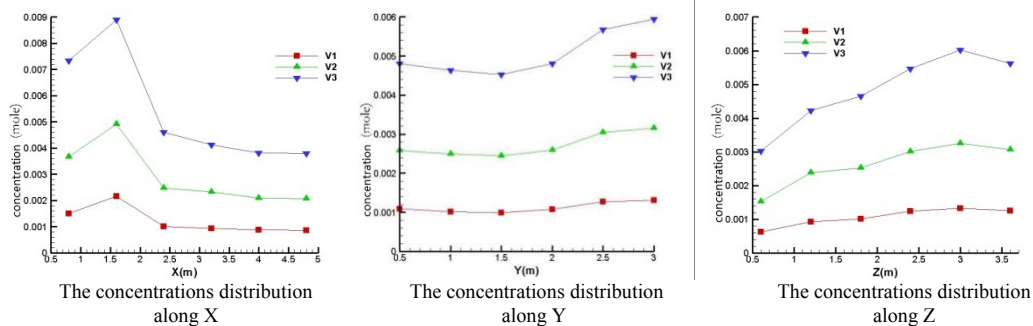


Fig. 12. The distribution of pollutant concentrations in work area under different pollutant emissions

According to Figure 12, pollutant concentrations of the room increased significantly along with the rising of pollution source concentrations. For the source concentrations can obviously affect the indoor pollutant concentrations, so we could effectively control the concentrations of pollutants in staff areas by control the pollutant emission from the source.

## 4. Discussion

This paper gets the same results with experiment only by software which saves the human and financial resources. However, we simplifies the simulation, just analysed the orifice plate air supply and didn't consider the effects of other air supply device. In a word, the designer and erector of air conditioning can also get some useful advice from this paper. However, this paper did not quantitative describe the relationship between the air supply rate

and the energy consumption, and the relationship between the air supply rate and the comfort. What's more, what kind of source controlling measure applies to this situation is also unsolved. Further research will be conducted to deal with the problems above.

## 5. Conclusions

This paper simulated the pollutant concentrations distribution under three different air supply modes, and analysed how the changed air supply rates and pollutant source concentrations effect the indoor pollutant concentrations distribution. The analysed conclusions are as following:

- Different air supply modes have obvious elimination effects and concentrations distribution on indoor pollutant. By comparing the distribution of pollutant concentrations near the special locations we choosed under the same fresh air volume condition, the air supply of up-inlet and down-outlet on the same side is more effective to clear pollutant.
- It is quite useful to clear the indoor pollutants by changing the air supply rate, but unconditionally increase air supply rate would inevitably lead to the increase of energy consumption and the decrease of the comfort of the room. Therefore, the demands of comfort and energy efficiency should be considered when raising the airflow. How to balance the needs of cleanliness, energy consumption and comfort still demands further studies.
- Source concentrations can also significantly affect the indoor pollutant concentrations. Therefore some effective measures must be taken to control indoor pollutant concentrations.

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